

Date: October 30, 2000

09/674415

Page 1

**TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US)  
CONCERNING A FILING UNDER 35 USC 371**

International Application No.: PCT/RU99/00149  
International Filing Date: April 30, 1999  
Priority Date Claimed: April 30, 1998, January 18, 1999  
Title of Invention: STABILIZED AND CONTROLLED ELECTRON SOURCES, MATRIX SYSTEMS OF THE ELECRON SOURCES, AND METHOD FOR PRODUCTION THEREOF  
Applicants for DO/EO/US: Evgeny Invievich Givargizov, Michael Evgenievich Givargizov, Vladimir Iliich Ershov, Nina Ivanovna Manshina

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1.  This is a **FIRST** submission of items concerning a filing under 35 USC 371.
2.  This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 USC 371.
3.  This express request to begin national examination procedures (35 USC 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 USC 371(b) and PCT Articles 22 and 39(1).
4.  A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5.  A copy of the International Application as filed (35 USC 371(c)(2))
  - a)  is transmitted herewith (required only if not transmitted by the International Bureau).
  - b)  has been transmitted by the International Bureau.
  - c)  is not required, as the application was filed in the United States Receiving Office (RO/US).
6.  A translation of the International Application into English (35 USC 371(c)(2)).
7.  Amendments to the claims of the International Application under PCT Article 19 (35 USC 371(c)(3))
  - a)  are transmitted herewith (required only if not transmitted by the International Bureau).
  - b)  have been transmitted by the International Bureau.
  - c)  have not been made; however, the time limit for making such amendments has NOT expired.
  - d)  have not been made and will not be made.
8.  A translation of the amendments to the claims under PCT Article 19 (35 USC 371(c)(3)).
9.  An oath or declaration of the inventor(s) (35 USC 371(c)(4)).
10.  A copy of the International Preliminary Examination Report with any annexes thereto, such as any amendments made under PCT Article 34.

Date: October 30, 2000

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Page 2

11.  A translation of the annexes, such as any amendments made under PCT Article 34, to the International Preliminary Examination Report under PCT Article 36 (35 USC 371(c)(5)).

**Items 11. to 16. below concern other document(s) or information included:**

12.  An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
13.  An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
14.  A substitute specification.
15.  A power of attorney and/or address letter.
16.  International Application as published.
17.  Small Entity Statement.
18.  PCT Form PCT/IPEA/402.
19.  PCT Form PCT/IB/308.
20.  PCT request form.
21.  A return prepaid postcard.
22.  A FIRST preliminary amendment. Please calculate fees after entering the attached Preliminary Amendment
23.  The following fees are submitted:

RECEIVED  
U.S. PATENT AND TRADEMARK OFFICE  
OCT 30 2000

U.S. Application No.  
09/674,415

International Application No.  
PCT/RU99/0140

Attorney Docket No.  
*#4 C. Binf*  
09/674415 GIVAR5.001APC

Date: January 29, 2001

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- (X) The fee of \$65 for submission of the Declaration after 30 months from the priority under 37 C.F.R. 1.492(e).
- (X) The fee of \$40 for filing of the Assignment document.
- (X) The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 11-1410. A duplicate copy of this sheet is enclosed.

SEND ALL CORRESPONDENCE TO:

KNOBBE, MARTENS, OLSON & BEAR, LLP  
620 Newport Center Drive  
Sixteenth Floor  
Newport Beach, CA 92660

*Adeel S. Akhtar*

Signature

Adeel S. Akhtar

Printed Name

(415) 954-4114

Registration Number

W:\DOCS\ASA\ASA-8126.DOC  
012901

The PTO did not receive the following listed item(s) 640 and Assignment

02/08/2001 MNNGUYEN 00000054 09674415

01 FC:215 55.00 DP  
02 FC:254 65.00 DP

U71 01474  
U.S. Application No.International Application No.  
PCT/RU999/00149Attorney Docket No.  
GIVAR5.001 APC

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Page 3**FEES**

<b>BASIC FEE</b>			\$1000	
<b>CLAIMS</b>	<b>NUMBER FILED</b>	<b>NUMBER EXTRA</b>	<b>RATE</b>	
Total Claims	37 - 20 =	17 ×	\$18	\$340
Independent Claims	5 - 3 =	2 ×	\$80	\$160
Multiple dependent claims(s) (if applicable)			\$270	\$0
<b>TOTAL OF ABOVE CALCULATIONS</b>			\$1500	

Reduction by 1/2 for filing by small entity (if applicable). Verified Small Entity \$750 statement must also be filed. (NOTE 37 CFR 1.9, 1.27, 1.28)

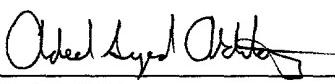
<b>TOTAL NATIONAL FEE</b>	\$750
<b>TOTAL FEES ENCLOSED</b>	\$750
amount to be refunded:	\$
amount to be charged:	\$

24.  A check in the amount of \$750 to cover the above fees is enclosed.
25.  Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40 per property.
26.  The Commissioner is hereby authorized to charge only those additional fees which may be required, now or in the future, to avoid abandonment of the application, or credit any overpayment to Deposit Account No. 11-1410. A duplicate copy of this sheet is enclosed.

**NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.**

SEND ALL CORRESPONDENCE TO:

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Adeel S. Akhtar  
Reg No. 41,349

89/674415

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GIVAR5.001APC

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant : E.I. Givargizov et al. ) Group Art Unit - Unknown  
Appl. No. : Unknown )  
Filed : Herewith )  
For : STABILIZED AND )  
CONTROLLED ELECTRON )  
SOURCES, MATRIX )  
SYSTEMS OF THE )  
ELECTRON SOURCES, AND )  
METHOD FOR )  
PRODUCTION THEREOF )  
Examiner : Unknown )  
)

I hereby certify that this correspondence and all  
marked attachments are being deposited with  
the United States Postal Service as first-class  
mail in an envelope addressed to Assistant  
Commissioner for Patents, Washington, D.C.  
20231, on

October 30, 2000  
(Date)

Adeel S Akhtar, Reg. No 41,394

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents  
Washington, D.C. 20231

Dear Sir:

Applicants respectfully request entry of the amended claims attached herewith.

IN THE CLAIMS:

Please cancel Claims 1-50.

Please add the following Claims 51-93:

51. An electron source comprising:
  - a substrate;
  - a field emitter, a body of the field emitter being a whisker epitaxial to the substrate;
  - a source of charge carriers supplying the field emitter; and
  - at least one ballast resistor configured as a barrier between different materials located in or proximate to the field emitter.

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52. The electron source of Claim 51, wherein the substrate comprises an insulating layer and a conductive layer.

53. The electron source of Claim 52, wherein at least one barrier is formed within the conductive layer of the substrate.

54. The electron source of Claim 51, wherein the substrate is a single crystal with (111) orientation.

55. The electron source of Claim 51, wherein the field emitter comprises at least one semiconductor material.

56. The electron source of Claim 51, wherein at least one barrier is formed, in part, by an insulating layer that is perpendicular to the direction of charge carrier flow.

57. The electron source of Claim 51, wherein the different materials are semiconductors with opposite conductivity types.

58. The electron source of Claim 51, wherein an end of the field emitter comprises a narrow tip.

59. The electron source of Claim 58, wherein the tip of the field emitter is sharpened and coated by diamond or diamond-like material.

60. The electron source of Claim 59, wherein the diamond or diamond-like material is sharpened.

61. The electron source of Claim 51, wherein the field emitter comprises two coaxial parts, a broad inner part and a more narrow outer part.

62. The electron source of Claim 51, wherein the barrier is formed within the field emitter body.

63. The electron source of Claim 51, wherein the barrier is formed between the field emitter body and a conducting layer placed directly on a surface of the field emitter.

64. The electron source of Claim 63, wherein the conducting layer comprises at least one semiconductor material.

65. The electron source of Claim 63, wherein there is an insulating layer at least part way between the conducting layer and the surface of the field emitter.

Appl. No. : Unknown  
Filed : Herewith

66. The electron source of Claim 51, wherein the source of the charge carriers is the conducting layer on the surface of the field emitter.

67. An electron source comprising:

a substrate;

a field emitter, a body of the field emitter configured as a blade;

a source of charge carriers supplying the field emitter; and

at least one ballast resistor configured as a junction between semiconductor materials with opposite conductivity types located in or proximate to the field emitter.

68. The electron source of Claim 67, wherein the substrate is a single crystal with (111) orientation.

69. A controlled electron source comprising:

a substrate having a surface and a field emitter extending from the surface;

a field emitter having a side surface with an insulating layer covering at least a portion of the side surface;

a source of charge carriers supplying the field emitter;

at least one ballast resistor configured as a junction between materials with opposite conductivity types located in or proximate to the field emitter; and

at least one control electrode in proximity to the junction.

70. The controlled electron source of Claim 69, wherein the field emitter, having a body, contains at least one active area that is at least, in part, in the body.

71. The controlled electron source of Claim 69, wherein a conducting layer covers at least part of the surface of the substrate and at least part of the surface of the field emitter, the layer containing at least, in part, one or more active areas.

72. The controlled electron source of Claim 69, wherein at least one control electrode is placed close enough to the junction to influence a flow of charge carriers therein.

73. The controlled electron source of Claim 69, wherein at least one control electrode is separated from the field emitter by a vacuum gap.

74. The controlled electron source of Claim 69, wherein at least one control electrode is placed along the side surface of the field emitter.

Appl. No. : Unknown  
Filed : Herewith

75. The controlled electron source of Claim 74, wherein the control electrode has direct contact with the side surface of the field emitter.

76. The controlled electron source of Claim 69, wherein a surface of the field emitter is coated by a material which is transparent to electrons, and which prevents outlet of chemical elements from the field emitter.

77. The controlled electron source of Claim 76, wherein the material comprises diamond or diamond-like carbon.

78. A matrix system of controlled electron sources arranged on a substrate comprising:

at least two controlled electron sources; and

parallel rows of conductive material on an insulating layer covering the substrate.

79. The matrix system of Claim 78, wherein the system is a two-dimensional array of the controlled electron sources arranged in rows that are approximately perpendicular to one another.

80. The matrix system of Claim 78, wherein the controlled electron sources receive electrical input from two sets of approximately parallel conductive buses that are approximately perpendicular to each other and that are separated from each other by an insulating layer.

81. The matrix system of Claim 78, wherein at least one control electrode has a diaphragm shape and comprises conductive diamond or diamond-like material.

82. A method of preparation of a controlled electron source comprising:

forming the field emitter as a whisker epitaxial to the substrate;

forming within the field emitter at least one junction between materials having opposite electrical conductivity, the boundary configured approximately perpendicular to a long direction of the whisker; and

forming at least one control electrode close enough to the junction to affect junction conductivity when a voltage is applied to the control electrode.

83. The method of Claim 82, wherein forming the field emitter as a whisker is done using a vapor-liquid-solid method.

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**Filed** : Herewith

84. The method of Claim 82, wherein forming the field emitter as a whisker comprises forming a cavity in the substrate; and depositing a solvent particle at a bottom of the cavity.

85. The method of Claim 82, wherein the forming of the field emitter on a substrate comprises placing a solvent particle on the substrate and etching the substrate around the solvent particle.

86. The method of Claim 82, wherein forming the field emitter on a substrate comprises:

depositing a solvent particle onto the substrate, the substrate having a first conductivity type;

using a first source material having a second conductivity type opposite to the first conductivity type to grow a portion of a whisker having a second conductivity type;

cooling the whisker, having a globule on its end, and also cooling the substrate using an inert gas;

removing the first source material;

heating the whisker having the globule on its end using an inert gas and the substrate; and

using a second source material having a first kind of conductivity to continue growing the whisker, thereby making a portion having the first conductivity type.

87. The method of Claim 86, wherein additional portions of the whisker are formed with alternating second and first conductivity types.

88. The method of Claim 82, wherein forming the field emitter comprises:

growing a whisker in a gas atmosphere that comprises elements of the substrate;

introducing doping gases into the gas atmosphere; and

changing the conductivity type of the doping gases at least once while forming the field emitter.

Appl. No. : Unknown  
Filed : Herewith

**REMARKS**

The Claims have been amended to conform more fully to U.S. patent practice. Applicants respectfully submit that the amendments add no new matter and are fully supported by the application as originally filed.

Respectfully submitted,  
KNOBBE, MARTENS, OLSON & BEAR, LLP

Dated: Oct. 30, 2000

By: Adeel Syed Akhtar

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Annex US.V, page 4

PCT Applicant's Guide – Volume II – National Chapter – US

GIVARG5.601APC

Applicant or Patentee: Givargizov Evgeny Invieovich Attorney's  
Serial or Patent No.: \_\_\_\_\_ Docket No.: \_\_\_\_\_  
Filed or Issued: 30 April 1999  
For: STABILIZED AND CONTROLLED ELECTRON SOURCES, MATRIX SYSTEMS OF THE ELECTRON SOURCES, AND METHOD FOR PRODUCTION THEREOF.

**VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 CFR 1.9 (f) and 1.27 (b)) — INDEPENDENT INVENTOR**

As a below named inventor, I hereby declare that I qualify as an independent inventor as defined in 37 CFR 1.9 (c) for purposes of paying reduced fees under section 41 (a) and (b) of Title 35, United States Code, to the Patent and Trademark Office with regard to the invention entitled STABILIZED AND CONTROLLED ELECTRON SOURCES, MATRIX SYSTEMS OF THE ELECTRON SOURCES, AND METHOD FOR PRODUCTION THEREOF.

the specification filed herewith  
 application serial no. \_\_\_\_\_, filed 30 April 1999  
 patent no. \_\_\_\_\_, issued \_\_\_\_\_

I have not assigned, granted, conveyed or licensed and am under no obligation under contract or law to assign, grant, convey or license, any rights in the invention to any person who could not be classified as an independent inventor under 37 CFR 1.9 (c) if that person had made the invention, or to any concern which would not qualify as a small business concern under 37 CFR 1.9 (d) or a nonprofit organization under 37 CFR 1.9 (e).

Each person, concern or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below:

no such person, concern, or organization  
 persons, concerns or organizations listed below\*

\*NOTE: Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)

FULL NAME Givargizov Evgeny Invieovich  
ADDRESS Obrucheva 20, kv. 12, Moscow 117421, Russia

INDIVIDUAL       SMALL BUSINESS CONCERN       NONPROFIT ORGANIZATION

FULL NAME \_\_\_\_\_  
ADDRESS \_\_\_\_\_

INDIVIDUAL       SMALL BUSINESS CONCERN       NONPROFIT ORGANIZATION

FULL NAME \_\_\_\_\_  
ADDRESS \_\_\_\_\_

INDIVIDUAL       SMALL BUSINESS CONCERN       NONPROFIT ORGANIZATION

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28 (b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

Givargizov E.I.

NAME OF INVENTOR

NAME OF INVENTOR

NAME OF INVENTOR

Givargizov

Signature of Inventor

Signature of Inventor

Signature of Inventor

September 18, 2000

Date

Date

Date

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526 Rec'd PCT/TTD 30 OCT 2000

PCT/RU99/00149

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STABILIZED AND CONTROLLED ELECTRON SOURCES,  
MATRIX SYSTEMS OF THE ELECTRON SOURCES,  
AND  
METHOD FOR PRODUCTION THEREOF

FIELD OF THE INVENTION

This invention relates to microelectronics, including vacuum microelectronics, in particular to field emission devices, specifically to field emission cathodes, as well as to other field emission devices such as field emission displays, electron sources for electron guns, for microwave devices, etc.

PRIOR ART

During last years, various versions for realization of field emission, including the emission with using of defects in planar structures, are considered, the defect acting as initiators of the field emission [1,2]. Field emitters (tips, blades, etc) prepared by special methods, as field emission initiators, have many advantages in comparison with the defects from the point of view of feasibility to realize regular multiple arrays of the field emitters and controlled growing of the arrays on large areas. However, cases are often occurs at the practice when the regular arrays are inferior to structures with an incidental distribution of the defects in homogeneity.

Troubles in stability and controllability of electron flows giving of by the field emitters are also known. Troubles with uniformity of the field electron emission of the multiple field emitter arrays are of the same nature. The uniformity is typically ensured by ballast resistors that equalize electron currents through different field emitters of the multiple field emitter arrays.

Various design and technological solutions are use for overcoming of the troubles (problems) with the field emitter.

A controlled electron source is known where the field emitter is connected to the drain of MOSFET that serves as a stable current electron source [3,4]. In such an electron source, the issue of stability and controllability of the field emission current is successfully solved. However, transistor p-n junctions in the electron source are placed in the substrate where the field emitter is placed, too, and a control electrode is arranged between the field emitter and a charge carrier source that is placed at the substrate, too. This increases significantly the area taken by a pixel and, accordingly, decreases the resolving power of field emission displays based on such electron sources.

A solution of the problems of stability and controllability combined with the spatial arrangement of the control components is successfully realized in the patent [5]. Here, in the electron source a diode is placed in the emitter base for the stability and the controllability of the field emission

current. Such a design decreases principally the sizes of the electron source three time, as minimum, because its control component takes the same place as the field emitter itself. Such an electron source allows to regulate the voltage so that the starting voltage for the field emission is decreased and, in such a way, the uniform emission is ensured. A plurality of emitters, acting through diodes and operating actually as ballast resistors, are placed onto the cathode electrode. Such a design ensures the uniformity of the field emission and, simultaneously, its controllability. However, the proposed in [5] components of stabilization and control of the field emission current are insufficient for successful solving of the problems of uniformity and controllability.

In the patent [6] a more complete using of the advantages of the field emitters is realized. The field emitter is considered as a spatially distributed object (various parts of which serve as functional components of a device) rather than as a "material point" of the field emission, without spatial characteristics of their various parts.

According to the patent [6] components for control of the electron source are transformed from the planar arrangements, as it was done in [3,4], into a vertical arrangement. Thus, a principal role in the stabilization and control of the field emission current is assigned (allocated), to the body and to the surface of the field emitter, in addition to the usual role of its top.

Similar to [3-5] in the patent [6] an extracting electrode acts to electrons placed in the emitter top. In [6] electron sources are considered where the field emitters have sufficient length and thickness. Therefore, from the point of the action of the control electrodes or barriers (such as the diode in [5]), as minimum four areas of the electron sources are considered:

- the substrate on which the field emitter is placed;
- the basis of the field emitters;
- the top of the field emitters;
- their bodies.

These are areas of selective activation, or active areas.

So, the active area is an area in the substrate, in body of the field emitter, in its basis or at its top. A connection of the source of the charge carriers with the field emitter is implemented through the areas, and a control of the field emission current (of the charge carriers flow) from one area to another by means of stimulation and extracting is implemented.

In some cases, however, such a control of the charge carrier flow can not be realized in [6]. This is related to the fact that the field emitter, being under the action of a rather high electric field, for example, of the anode one, is subjected to its influence not only to the area of the top of field emitter but also all over the body. As a result, such electric field, acting to the field emitter, "shorts out" an action various barriers and over control components. The method for preparation of the field emitters by "wet" or "dry" etching used in the patent [6] results in formation of the emitters having small ratios of the length  $l$  of the active area to its diameter  $d$ . In this case, for controlling of the field emission current, too large voltage must be used in order to compensate the action of the large external (for example, of anode) electric field.

Indeed, if the field emitter, containing a part with the p-type conductivity is placed in the electric field  $E$  (Fig. 3C), formed by the anode, the boundary of the first of the first p-n junction 04 is

shifted  $E_j$  to the p-area. At a certain value  $E$ , the first junction  $04$  approaches to the second one  $06$  in such an extent that the electrons from the n-area  $c$  begin tunneling through the narrowed barrier to the field emitter. This causes emission of electrons from field emitter. This is the "shorting out" under the external electric field. Existence of the control electrode near the field emitter both in traditional (Fig. 3A) and in the considered [6] version (Fig. 3B) can compensate the action of the penetrating electric field and, such a manner, to "lock" the charge carriers of the second n-area  $c$ . However, it is known that, at the geometric sizes, considered in [6], the length  $l$  of the p-area is compatible with or and even shorter than the width  $d$ . As it is known, for "locking" of the charge carriers value of the traverse electric field of the control electrode  $02$  or  $08$  must be comparable with the longitudinal field responsible for the charge carrier flow. This makes it necessary to apply large voltages to the control electrodes.

In addition, in the patent [6] the control electrodes stimulate the flowing of the charge carriers through the active area and extract the electrons from the field emitter. In such a way, the electron emission is stabilized and controlled. At the same time the control electrodes in [6] does not lock the flow of the charge carriers through the active area. The above function of the control electrodes – to stimulate the flowing of the charge carriers, makes it necessary mentioned in [6] approximate sizes of p-area as "... formed to no more than several microns in thickness and generally to submicron order thickness" (see column 8, last paragraph in [6]). This means that the authors of [6] did not consider a possibility to provide the control electrode by "locking" function and, as a result, they considered the design is which enough just for stimulation and which is not enough for locking the electrons move under the influence of strong external electric field. However, it is known that if the control electrodes can lock the flow, it is possible to use small (in absolute value) negative voltage for the locking of the flow. The just mentioned approach is very important from practical point of view – to use low voltage "electric keys" in different driving systems, for example, in the field emission displays. Such a version can not be realized in [6] due to small value of the characteristic  $l/d$  that is there approximately equal to 1 which is provided by the design proposed in [6].

In this invention, the drawback is overcome owing to the fact that, here, for stabilization and controlling of the field emission, a whisker ("filament crystal") characterized by  $l/d \gg 1$  is used. A method for preparation of the whiskers with traverse p-n junctions is also proposed in this invention. As a result, the design proposed allows to control the field emission by locking the charge carrier flow.

The approach proposed is especially important at creation of effective long-living flat panel displays. Indeed, the higher the anode (accelerating) electric field, the more effective and long-living are their phosphors because, the efficiency is larger at higher voltages. Also at the increasing of anode voltage in such devices and, accordingly, decreasing of the current the durability of the phosphors is increased. The high accelerating voltage allows to use a protecting coating layer (for example, aluminum) that prevents the decomposition of the phosphors and increases the illumination owing to the light reflection. In addition, the decreasing currents are useful for the field emitters themselves (especially of semiconductor emitters) because at high currents the emitters are heated resulting in their degradation.

In this invention various possibilities for the stabilization and control of the field emission current based on using of epitaxially grown whiskers are proposed. By whisker growing, the ratio  $l/d$

can implemented as 5-10 and more times. In addition, with the whisker grown field emitters broad possibility for shape variation and creation of the control electrodes can be realized. In particular, a design with step-shaped emitter is proposed Fig. 4c.

According to this invention, the field emitter is implemented of whisker that includes at least one barrier (for example, n, n+, p, p+ or p-n junction), e.i., the barrier is placed in the body of the field emitter, being at some height  $h>0$  (Fig. 4a) above the substrate, e.i., above its own basis. At the same time in the patents [3,5] one of the barrier is placed at the basis of the field emitter being either at the upper level of the substrate or below it.

As it was mentioned above the active area can be placed both in the basis of field emitter [5], top [3,5] or substrate [3], and in the body of the field emitter [6]. In this invention a version is proposed when the active area is placed on side surface of the field emitter or in the body of the material that has direct or indirect contact with substrate or field emitter.

The active area can be placed also in thin surface conductive layer arranged on an insulating substrate. Thus, the version of the controlling electron source as purposed in this invention not only has solved the problem of transferring the stabilizing and controlling components from their planar arrangement to vertical one (and, in such a way, of increasing the resolution of the device) but also allows to conserve the controllability of the emission current by means of low voltage. In such a way, this allows to realize said controllability both in the case of low and high external electric field.

In the patent [6], as it was mentioned above, the method for fabrication of the field emitters with traverse p-n junctions. However, this method does not allow to obtain optimal geometric parameters of the field emitter that gives necessary functional characteristics.

The methods for growing oriented whiskers arrays are known [7, 8, 9, 10]. The methods, however, does not contain procedures for preparation of the junction, for example, like p-n. In this invention, such procedures are proposed.

#### SUMMARY OF THE INVENTION

An electron source is proposed, the source including a field emitter, a substrate, a source of charge carriers, and at least one ballast resistor. The field emitter is implemented of a whisker epitaxially grown on the substrate, and at least one ballast resistor is implemented as a barrier which is represented as a boundary in the body of the field emitter. The boundary is formed by a contact of materials with different kinds of conductivity.

In the electron source the field emitter is implemented of at least one semiconductor material. At least one barrier in the electron source is formed by junction of materials with different kinds of conductivity, such as n, n+, p, p+ kinds. At least one barrier is formed by an insulating layer that is across to direction of charge carriers flow.

The field emitters is formed by a tip, the tip consisting of two coaxial parts, a broad lower part and a more narrow upper part. The field emitter can be also formed by a blade. The tops of the field emitters are sharpened and coated by diamond or diamond-like material, and the coatings can be sharpened, too.

At another version of the electron source the barrier is formed by a boundary between a body of the field emitter and a conducting layer placed on a surface of the field emitter. In the electron source, at least one ballast resistor is implemented as a barrier which is represented as a boundary in the field emitter body, the boundary being formed by contacts of the materials with different kinds of conductivity.

The field emitter is implemented of at least one semiconductor material, and the conducting layer is also implemented of at least one semiconductor material.

At least one barrier in the field emitter is formed by junction of materials with different kinds of conductivity, such as n, n+, p, p+ kinds.

In another version of the electron source at least one barrier is formed by an insulating layer that is across to the direction of charge carriers flow.

The field emitter can be formed either by a tip or by a blade. In the case of the tip shape the field emitter consists of two coaxial parts, a broad lower part and a more narrow upper part. The top of the field emitter is sharpened and coated by diamond or diamond-like material, the coating being sharpened, too.

The source of the charge carriers is connected to the field emitter via substrate and/or a conducting layer placed on a surface of the field emitter directly or via an insulating layer.

In one more version of the electron source the substrate has a shape of a tip and is formed by an insulator and by a conductive layer, the ballast resistor being implemented by the layer.

The conductive layer in the electron source contains at least one barrier for charge carriers. At least one barrier in the electron source is formed by junction of materials with different kinds of conductivity, such as n, n+, p, p+ kinds, and at least one barrier is formed by insulating layer that is across to direction of charge carriers flow.

In one more version the electron source can be controlled containing at least one control electrode. The electron source can contain at least one active area in the body and/or on the surface of the field emitter. The active area can be realized in conducting layer placed on the surface of the substrate and/or of the field emitter directly or via an insulator layer.

At least one control electrode is placed close to one barrier for the charge carriers or on side surface of the field emitter via an insulator layer. The control electrode is separated from the field emitter by a vacuum gap or placed along the field emitter. The control electrode can have a direct contact with the side surface of the field emitter.

The substrate in the controlled electron source can be crystalline, or can be implemented by an insulator and a conductive layer placed on the insulator. The substrate can be implemented of the single-crystalline material with orientation (111).

The surface of the substrate can be coated by a material which is transparent for electrons and which prevents outlet of chemical elements from the surface of the controlled electron source, the material being diamond or diamond-like carbon.

The invention is also considered a matrix of the controlled electron sources containing at least two controlled electron sources. The matrix can contain a two-dimensional system of mutually perpendicular rows of the controlled electron sources, at least one of the control electrode of the

electron sources having a diaphragm shape and being implemented of diamond or diamond-like material.

The substrate on which the controlled electron source are arranged is implemented of conductive material placed on an insulator.

The matrix contains conductive buses which form two systems where buses of each of the systems are mutually parallel whereas the buses of two different systems are mutually perpendicular, the systems the two systems being placed in two levels and separated by an insulating layer.

This invention proposes also a method for preparation of controlled electron sources including a formation on a solid substrate of field emitters each of that contains at least one transverse junction formed by materials having different electrical conductivity, a formation of at least one controlled electrode close to such junctions, where the field emitters are implemented of whiskers epitaxially grown by the vapor-liquid-solid mechanism. The implementation of the field emitters can includes formation of the hollows in the substrate and deposition of solvent particles at the bottom of the hollows. The implementation of the field emitters can also includes placing of solvent particles on the substrate and etching of the substrate around the particles.

According to mentioned above the method can includes further procedure for formation of the field emitters, that is to say, placing of a source material, having a first kind of conductivity, opposite to the substrate with the solvent particles on it, growing of whiskers having the first kind of conductivity, stabilized cooling of the grown whiskers, having the globules on its tops, with an introduction of an inert gas into atmosphere, with simultaneous decreasing of the temperature of the substrate, changing of the source material for another source having a second kind of conductivity, stabilized heating of the grown whiskers, having the globules on its tops, with an introduction of an inert gas into atmosphere, with simultaneous increasing of the temperature of the substrate, and growing of whiskers having the second kind of conductivity. The method also include possibility to change the source materials more than two times.

According to mentioned above the method can also includes further procedure for formation of the field emitters includes growing of whiskers in a gaseous atmosphere containing the element or elements of which the substrate consists, introduction of doping gaseous compounds into the gas atmosphere. According to the method the formation of the field emitters can includes more than one procedure of introduction into the gas atmosphere of different gaseous doping compounds.

#### BRIEF DESCRIPTION OF DRAWINGS

**Fig. 1.** Illustration of the field emission cathode according to the prior art [5].

1 – substrate; 2 – cathode; 3 – diode; 4 – metallic layer; 5 – semiconductor layer; 6 – emitter; 7 – insulating layer; 8 – control electrode.

**Fig. 2a, 2b.** Illustrations of the field emission devices according to the prior art [3].

**Fig. 3a, 3b.** Illustrations of the field emission devices according to the prior art [6].

01 – top of field emitter; 02 – control electrode; 03 – insulator; 04 – barrier (junction); 06 – barrier (junction); 08 – control electrode; 09 – conductive part of substrate; 09i – insulator part of substrate; a, b, c – areas of various conductivity kinds; e – position of active areas.

**Fig 3c.** Illustration of the field emitter with various function areas of the prior art.

E – external electric field; E<sub>j</sub> - various positions of junction boundary (for example, p-n) under the influence of external electric fields of various value; E<sub>t</sub> – position of junction boundary when electrons start to flow through junction; l – length of the active area; d – width of the active area.

**Fig. 3d.** Illustration of the method for preparation of the field emitter according to [6].

12, 13, 14 – layers with different kinds of conductivity.

**Fig. 4a, 4b, 4c, 4d, 4e.** Illustrations of the stabilized electron sources according to the present invention.

q – possible movement of charge carriers; h – height of the position of the barrier above the substrate; 00 – insulator if charge carriers are provided via surface layer; 00 – conductive material if charge carriers are provided via substrate.

**Fig. 5a, 5b, 5c, 5d.** Illustrations of the controlled electron sources according to the present invention

**Fig. 6a.** Illustration of the matrix system of the controlled electron sources according to the present invention.

07 – aperture.

Rows of control electrodes 02 and 08 are mutually perpendicular , and together realize the controlling of the emission of the matrix system.

**Fig. 6b.** Illustration of the matrix system of the controlled electron sources according to the present invention.

Rows of control electrodes 02 and rows of conductive stripes 09 of substrate based on insulate part 09i of the substrate are mutually perpendicular , and together realize the controlling of the emission of the matrix system.

**Fig. 7.** Illustration of grown silicon whisker with transversal barriers (junctions)

15 – solidified globule consisting of crystallites of silicon and solvent; by acting to the whisker with a chemical etch of silicon, the whisker is transformed into tip with simultaneous removal of the globule.

#### BEST VERSION FOR REALIZATION OF THE INVENTION.

**EXAMPLE 1.** A most typical version for realization of the stabilized electron sources that uses a barrier as a ballast resistor is the following. A thin layer of n-type silicon is deposited onto p-type silicon tip that epitaxial to substrate (Fig. 4d). The junction between the p-type of silicon and the n-type silicon coating acts as a ballast resistor.

**EXAMPLE 2.** A most typical version for realization of the controlled electron sources that uses a vertical arrangement of the control components is the following. The tip contains in its body two p-n junctions. An upper part of the tip is implemented of n-type material. A lower part of the tip as well

as the adjacent substrate are implemented of n-type material. A control electrode is placed at a middle part of the tip which is implemented of p-type material. The control electrode has an extended length, is placed on the surface of the tip and has with it a direct contact (Fig. 5c). When a voltage  $V_{open}$  is applied to the control electrode, an inverse layer is induced at the area *b* along the surface of the field emitter, and electrons from the area *c* begin to penetrate into area *a* through the inverse layer. Then the electrons are emitting from the field emitters under the action of the anode voltage.

EXAMPLE 3. A most typical version for realization of the matrix system of the controlled electron sources that uses the vertical arrangement of the control components is the following.

Rows of sharpened whisker-grown field emitters 01 are formed on a conducting substrate 09 of silicon having the crystallographic orientation (111), see Fig. 6a. A system of parallel rows of control electrodes 08 is formed on the surface of the field emitters, the insulating layers 03 being placed between the field emitters and the control electrodes. Then, an insulating glass layer 03' is deposited on the structure. After that, a set of parallel stripes 02 is deposited onto the glass, and centrosymmetrical cavities 07 are formed at the places corresponding to the emitters so that the upper ("top") of each of the emitters are in the centers of the cavities being risen above their bottoms. It is important that the set of the stripes 02 is perpendicular to the system of parallel rows of the control electrode 08. In order to obtain an emission from a given field emitter, it is necessary to apply a voltage  $V_{open}$  to a row in the system of the control electrodes 08 and, simultaneously, to apply a voltage  $V_{ext}$  to a stripe in the set 02. At the cross of the row and of the stripe, the sum voltage  $V_{open} + V_{ext}$  initiates the emission.

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## CLAIMS

**1.** An electron source that includes a field emitter, a substrate, a source of charge carriers, at least one ballast resistor, wherein

the field emitter is implemented of a whisker epitaxially grown on the substrate; at least one ballast resistor is implemented as a barrier which is represented as a boundary in the body of the field emitter, the boundary being formed by contact of materials with different kinds of conductivity.

**2.** The electron source according to the claim 1, wherein the field emitter is implemented of at least one semiconductor material.

**3.** The electron source according to the claim 2, wherein at least one barrier is formed by junction of materials with different kinds of conductivity, such as n, n<sup>-</sup>, p, p<sup>-</sup> kinds.

**4.** The electron source according to any of the claims 1-3, wherein at least one barrier is formed by an insulating layer that is across to the direction of the charge carriers flow.

**5.** The electron source according to any of the claims 1-4, wherein the field emitter is formed by a tip.

**6.** The electron source according to any of the claims 1-5, wherein the field emitter consists of two coaxial parts, a broad lower part and a more narrow upper part.

**7.** The electron source according to any of the claims 1-4, wherein the field emitter is formed by a blade.

**8.** The electron source according to any of the claims 1-7, wherein the top of the field emitter is sharpened and coated by diamond or diamond-like material.

**9.** The electron source according to the claim 8, wherein the diamond or diamond-like coating is sharpened.

**10.** An electron source that includes a field emitter, a substrate, a source of charge carriers, at least one ballast resistor, wherein

the field emitter is implemented of a whisker epitaxially grown on the substrate; at least one ballast resistor is implemented as a barrier formed by a boundary between a field emitter body and a conducting layer placed on a surface of the field emitter.

**11.** The electron source according to the claim 10, wherein at least one ballast resistor is implemented as a barrier which is represented as a boundary in field emitter body, the boundary being formed by contact of the materials with different kinds of conductivity.

**12.** The electron source according to any of the claims 10, 11, wherein the field emitter is implemented of at least one semiconductor material.

**13.** The electron source according to any of the claims 10-12, wherein the conducting layer is implemented of at least one semiconductor material.

**14.** The electron source according to any of the claims 10-13, wherein at least one barrier is formed by junction of materials with different kinds of conductivity, such as n, n<sup>-</sup>, p, p<sup>-</sup> kinds.

15. The electron source according to any of the claims 10-14, wherein at least one barrier is formed by insulating layer that is across to direction of charge carriers flow.

16. The electron source according to any of the claims 10-15, wherein the field emitter is formed by a tip.

17. The electron source according to any of the claims 10-16, wherein the field emitter consists of two coaxial parts, a broad lower part and a more narrow upper part.

18. The electron source according to any of the claims 10-15, wherein the field emitter is formed by a blade.

19. The electron source according to any of the claims 10-18, wherein the top of the field emitter is sharpened and coated by diamond or diamond-like material.

20. The electron source according to the claim 19, wherein the diamond or diamond-like coating is sharpened.

21. The electron source according to any of the claims 10-20, wherein the source of the charge carriers is connected to field emitter via substrate and/or a conducting layer placed on a surface of the field emitter directly or via an insulator layer.

**22.** An electron source that includes a field emitter, a substrate, a source of charge carriers, at least one ballast resistor, wherein

the substrate has a shape of a tip and is formed by insulator and by a conductive layer;  
the ballast resistor is implemented by the layer.

23. The electron source according to the claim 22, wherein the conductive layer contains at least one barrier for charge carriers.

24. The electron source according to any of the claims 22, 23, wherein at least one barrier is formed by junction of materials with different kinds of conductivity, such as n, n<sup>+</sup>, p, p<sup>+</sup> kinds.

25. The electron source according to any of the claims 22-24, wherein at least one barrier is formed by insulating layer that is across to direction of charge carriers flow.

**26.** A controlled electron source that includes a field emitter, a substrate, a source of charge carriers, at least one ballast resistor and at least one control electrode, wherein

it contains an electron source implemented according to claims 1-25.

27. The controlled electron source according to the claim 26, wherein it contains at least one active area in the body and/or on the surface of the field emitter.

28. The controlled electron source according to any of the claims 26, 27, wherein it contains at least one active area in a conducting layer placed on the surface of the substrate and/or of the field emitter directly or via an insulator layer.

29. The controlled electron source according to any of the claims 26-28, wherein at least one control electrode is placed close to one of the barrier for charge carriers.

30. The controlled electron source according to any of the claims 26-29, wherein at least one control electrode placed on side surface of the field emitter via an insulator layer.

31. The controlled electron source according to any of the claims 26-30, wherein it contains at least one control electrode that is separated from the field emitter by a vacuum gap.

32. The controlled electron source according to any of the claims 26-31, wherein at least one control electrode placed along the field emitter.

33. The controlled electron source according to any of the claims 26-32, wherein control electrode has a direct contact with the side surface of the field emitter.

34. The controlled electron source according to any of the claims 26-33, wherein the electron source according to any of the claims 1-21 a substrate is crystalline.

35. The controlled electron source according to any of the claims 26-34, wherein the electron source according to any of the claims 1-21 a substrate is implemented by an insulator and a conductive layer placed on the insulator.

36. The controlled electron source according to any of the claims 34, 35, wherein the substrate or the conductive layer of the substrate is implemented of the monocrystalline material with orientation (111).

37. The controlled electron source according to any of the claims 26-36, wherein its surface is coated by a material which is transparent for electrons, and which prevents outlet of chemical elements from the surface of controlled electron source.

38. The controlled electron source according to the claim 37, wherein the material is diamond or diamond-like carbon.

**39.** A matrix system of the controlled electron sources containing at least two controlled electron sources, wherein

at least one of the sources implemented according to any of the claims 26-38.

40. The matrix system according to the claim 39, wherein it contains a two-dimensional system of mutually perpendicular rows of the controlled electron sources.

41. The matrix system according to any of the claims 39, 40, wherein at least one control electrode in the controlled electron sources has a diaphragm shape and is implemented of conductive diamond or diamond-like material.

42. The matrix system according to any of the claims 39-41, wherein the substrate represents rows of conductive material placed on insulator.

43. The matrix system according to any of the claims 39-42, wherein the controlled electron sources are provided by conductive buses which form two systems buses of each of the systems are mutually parallel, the buses of the two different systems are mutually perpendicular, the two systems being placed in two levels and separated by insulator.

**44.** A method for preparation of controlled electron sources including  
a formation on a solid substrate of field emitters each of that contains at least one transverse junction formed by materials having different electrical conductivity;  
a formation of at least one controlled electrode close to such junctions;  
wherein  
the field emitters are implemented of whiskers epitaxially grown by the vapor-liquid-solid mechanism.

45. The method according to the claim 44, wherein the implementation of the field emitters includes

formation of the hollows in the substrate;  
deposition of solvent particles at the bottom of the hollows.

46. The method according to the claim 44, wherein the implementation of the field emitters includes

placing of solvent particles on the substrate;  
etching of the substrate around the particles.

47. The method according to any of the claims 45, 46, wherein further procedure for formation of the field emitters includes

placing of a source material, having a first kind of conductivity, opposite to the substrate with the solvent particles on it;

growing of whiskers having the first kind of conductivity;

stabilized cooling of the grown whiskers, having the globules on its tops, with an introduction of an inert gas into atmosphere, with simultaneous decreasing of the temperature of the substrate;

changing of the source material for another source having a second kind of conductivity;

stabilized heating of the grown whiskers, having the globules on its tops, with an introduction of an inert gas into atmosphere, with simultaneous increasing of the temperature of the substrate;

growing of whiskers having the second kind of conductivity;

48. The method according to the claim 47, wherein the change of the source materials is implemented more than two times.

49. The method according to any of the claims 45, 46, wherein further procedure for formation of the field emitters includes

growing of whiskers in a gaseous atmosphere containing the element or elements of which the substrate consists;

introduction of doping gaseous compounds into the gas atmosphere.

50. The method according to the claim 49, wherein the formation of the field emitters includes more than one procedure of introduction into the gas atmosphere of different gaseous doping compounds.

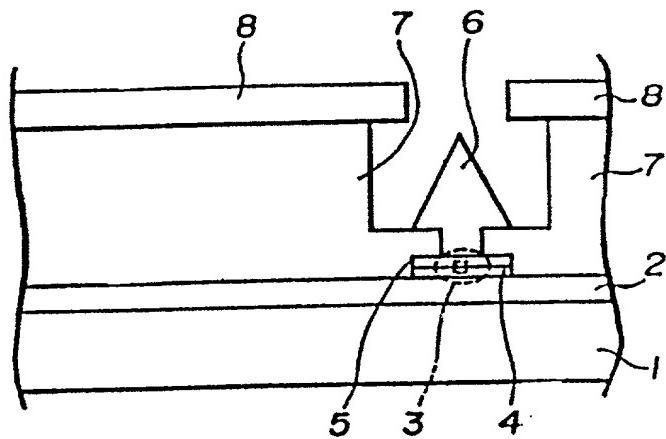


Fig. 1

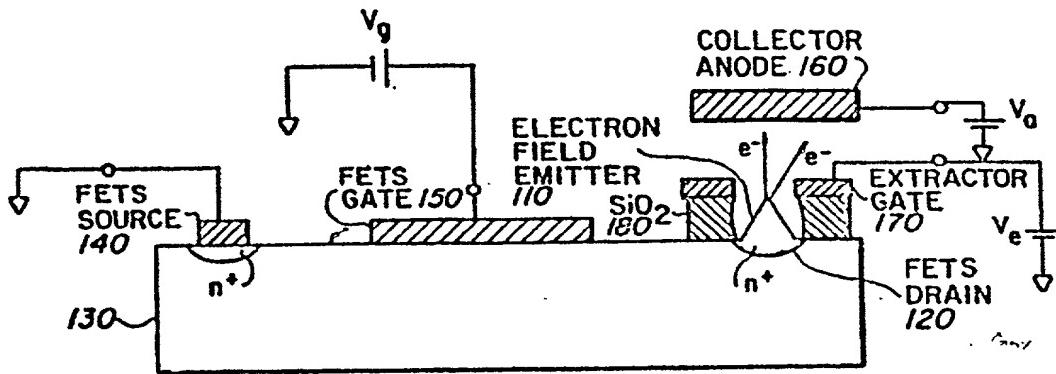


Fig. 2a

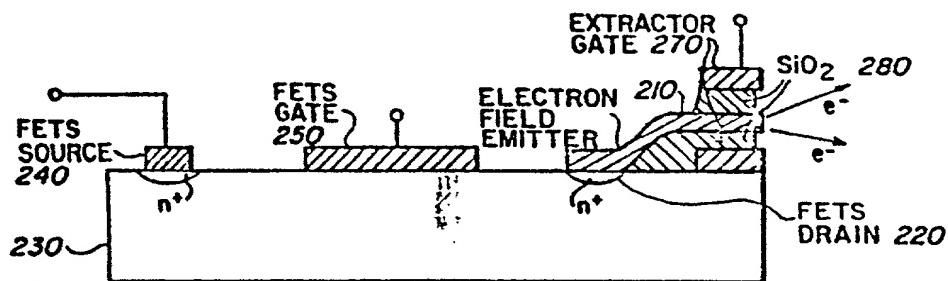
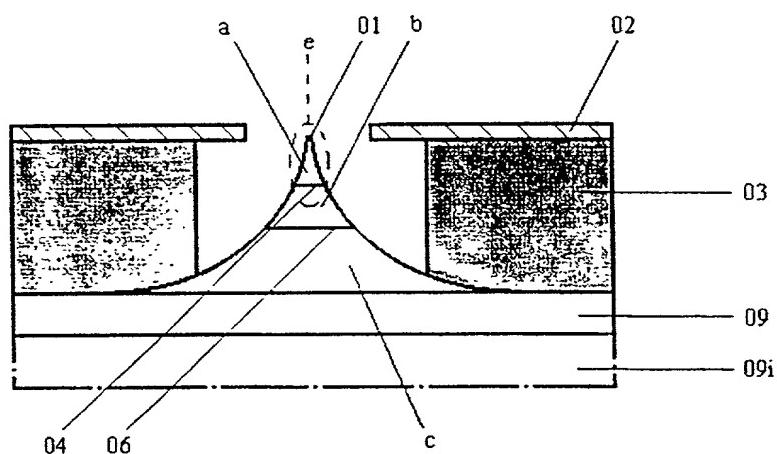
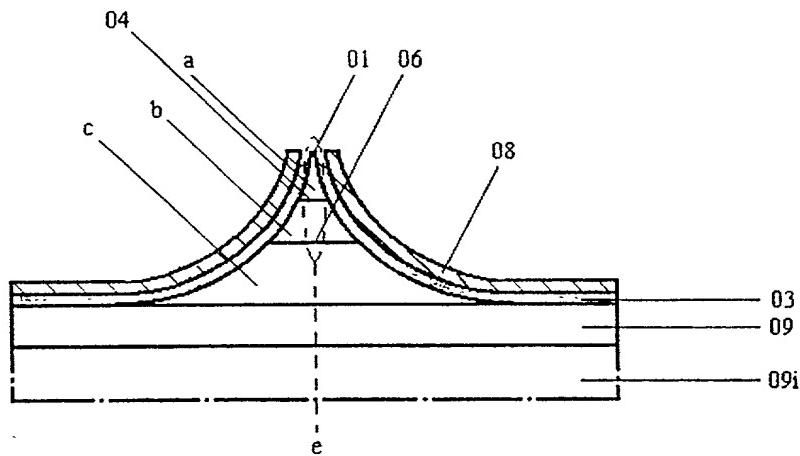
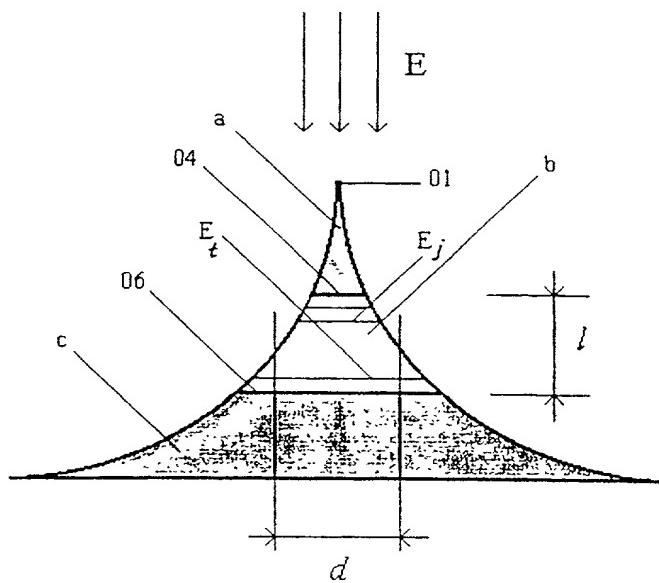
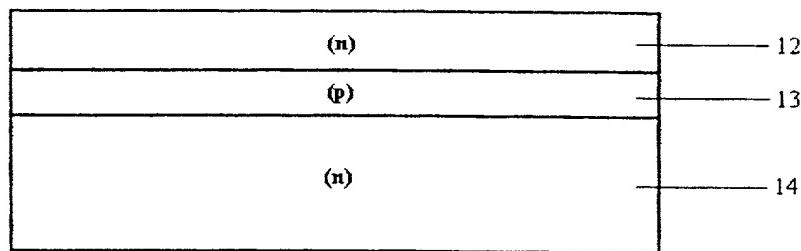


Fig. 2b

**Fig. 3a****Fig. 3b**

**Fig. 3c****Fig. 3d**

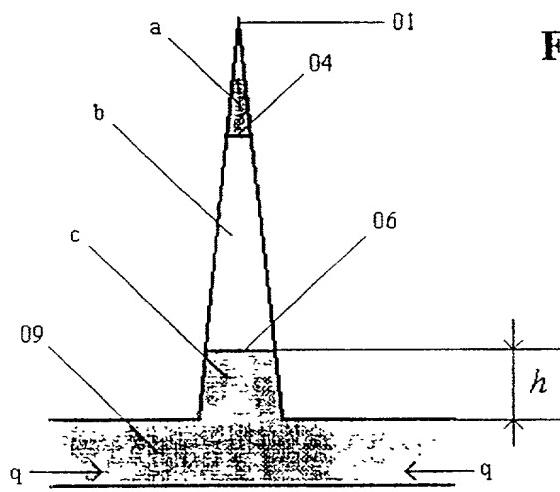


Fig. 4a

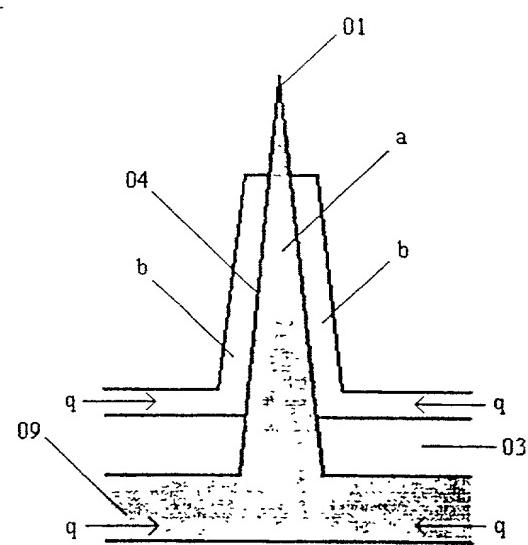
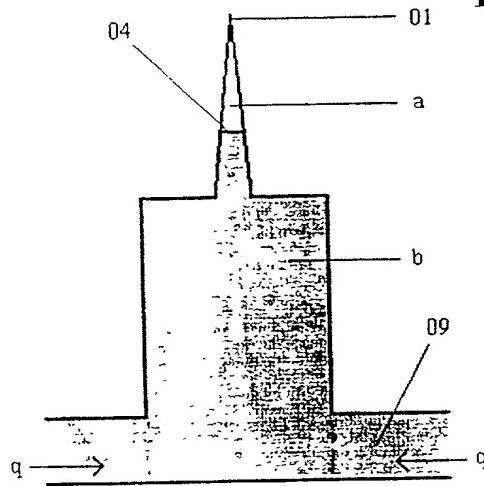
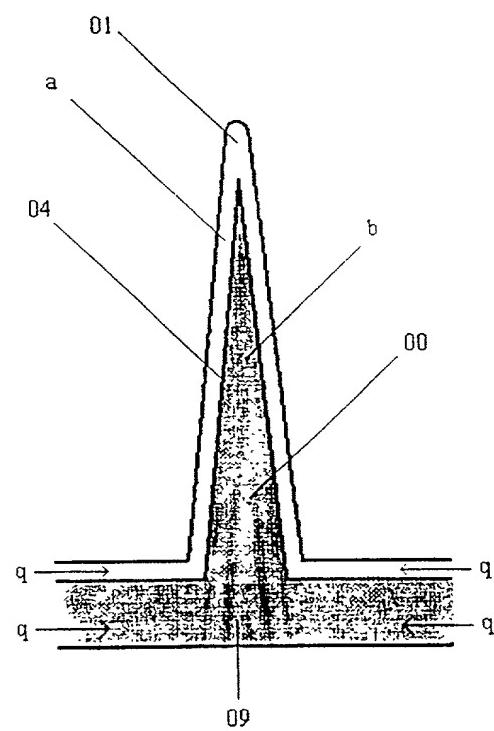
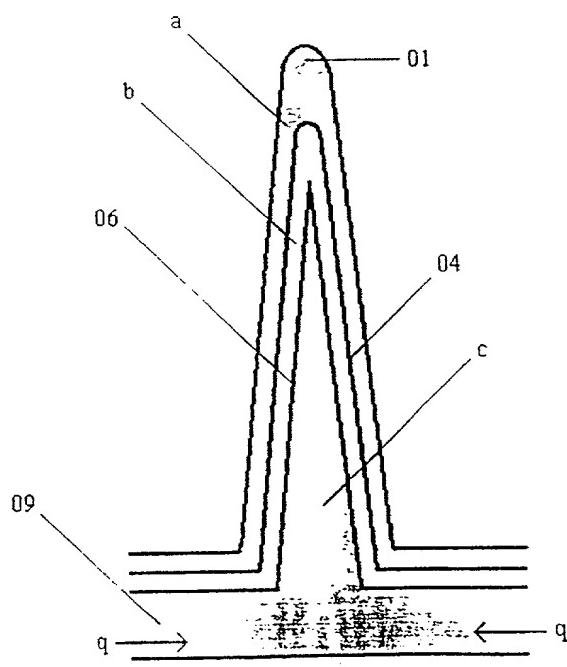


Fig. 4b

**Fig. 4c****Fig. 4d****Fig. 4e**

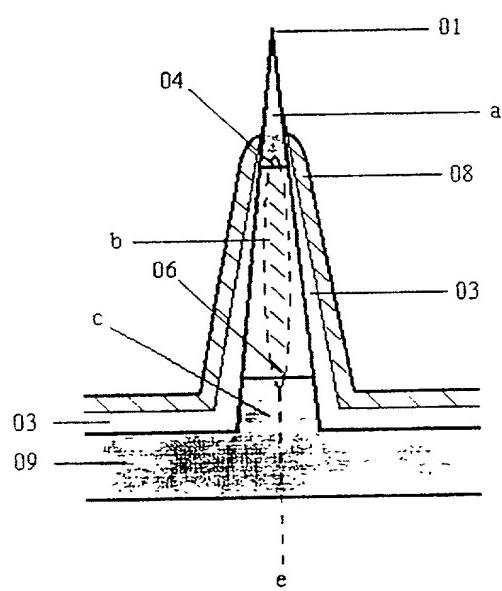


Fig. 5a

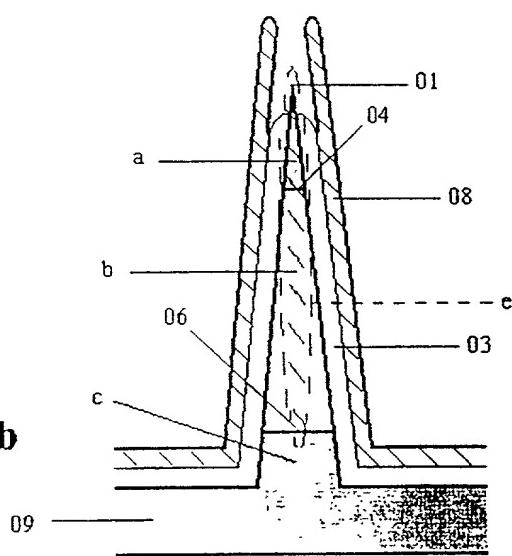
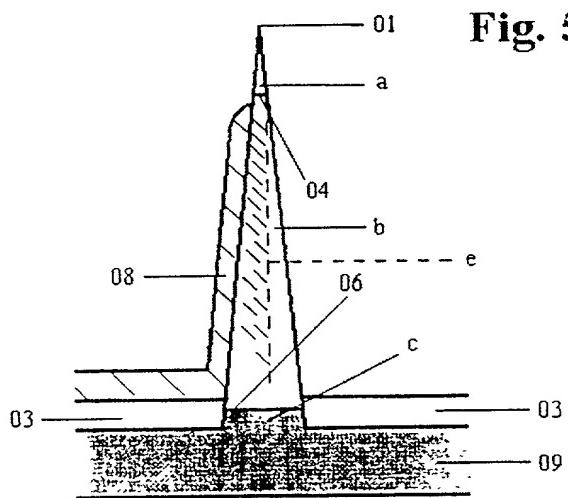
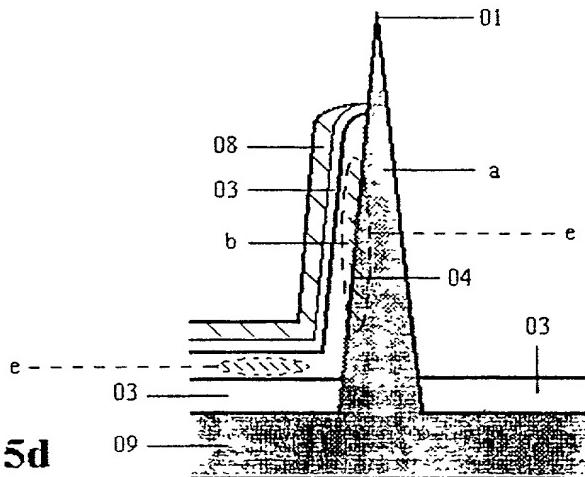


Fig. 5b

**Fig. 5c****Fig. 5d**

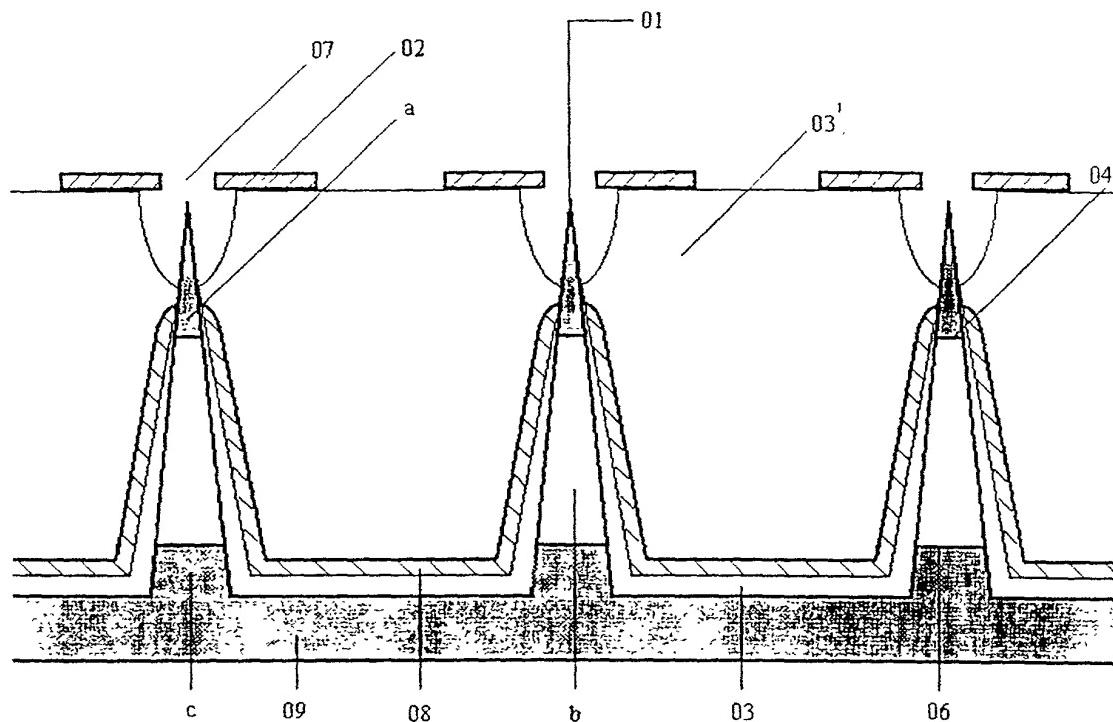


Fig. 6a

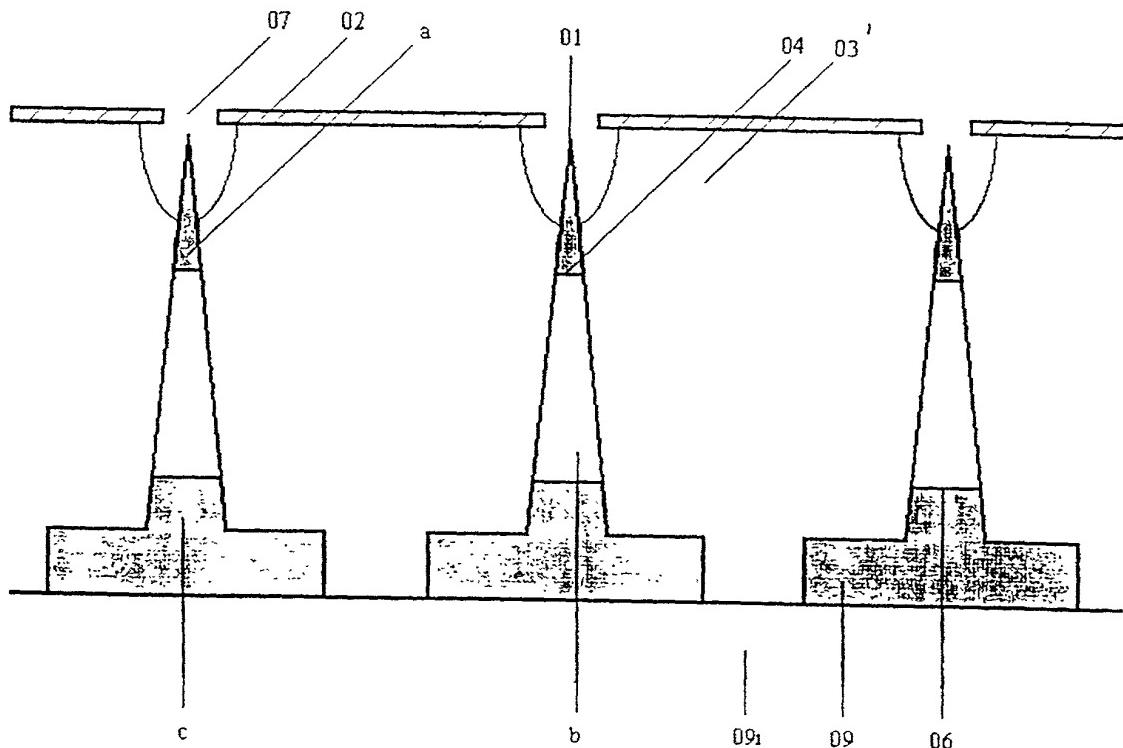


Fig. 6b

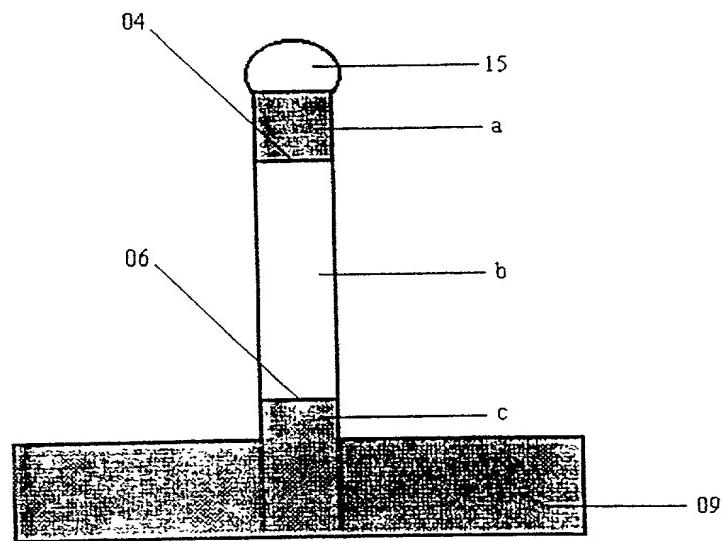


Fig. 7

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Attorney's Docket No. GIVARS.001APC

**DECLARATION AND POWER OF ATTORNEY - USA PATENT APPLICATION**

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name;

I believe I am the first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **STABILIZED AND CONTROLLED ELECTRON SOURCES, MATRIX SYSTEMS OF THE ELECTRON SOURCES, AND METHOD FOR PRODUCTION THEREOF** the specification of which:

- (a)  is attached hereto; or
- (b)  was filed on October 20, 2000 as Application No. 09/674,415;
- (c)  was described and claimed in PCT International Application No. PCT/RU99/00149 filed on April 30, 1999 and as amended under PCT Article 19 on \_\_\_\_\_ (if any) and/or under PCT Article 34 on \_\_\_\_\_ (if any).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above;

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, § 1.56;

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent, design or inventor's certificate or any PCT international application(s) listed below and have also identified below any foreign application(s) for patent, design or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed for the same subject matter having a filing date before that of the application(s) of which priority is claimed:

**PRIOR FOREIGN APPLICATION(S)**

COUNTRY (OR INDICATE IF PCT)	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 37 U.S.C. § 119	
Russian Federation	98109078	April 30, 1998	<input checked="" type="checkbox"/> YES	<input type="radio"/> NO
Russian Federation	99101033	January 18, 1999	<input checked="" type="checkbox"/> YES	<input type="radio"/> NO
			<input type="radio"/> YES	<input type="radio"/> NO

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) listed below, and insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code § 112, I acknowledge the duty to disclose to the U.S. Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56, which became available between the filing date of the prior application and the national or PCT international filing date of this application:

**Prior U.S.A. Application(s)**

Application No.: \_\_\_\_\_ Filing Date: \_\_\_\_\_ Status: \_\_\_\_\_

**POWER OF ATTORNEY:** I hereby appoint the registrants of Knobbe, Martens, Olson & Bear, LLP, 620 Newport Center Drive, Sixteenth Floor, Newport Beach, California 92660, Telephone (949) 760-0404, Customer No. 20,995.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful, false statements may jeopardize the validity of the application or any patent issued thereon.

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